

We claim:

1. An organic light emitting device comprising:
an anode;
a hole transporting layer over the anode, wherein the hole transporting layer is doped with a phosphorescent material;
an electron transporting layer over the hole transporting layer, wherein the electron transporting layer is doped with the phosphorescent material; and
a cathode over the electron transporting layer.

2. The organic light emitting device of claim 1, wherein the organic light emitting device emits light in the blue range of the visible spectrum.

3. The organic light emitting device of claim 1, wherein the hole transporting layer comprises a member of the group consisting of 4,4'-bis[N-(1-naphthyl)-N-phenyl-amino]biphenyl (α -NPD), N,N'-diphenyl-N,N'-bis(3-methylphenyl)-1,1'-biphenyl-4,4'-diamine (TPD), 4,4'-bis[N,N'-(3-tolyl)amino]-3,3'-dimethylbiphenyl (M14), 4,4',4''-tris(3-methylphenylphenylamino)triphenylamine (MTDATA), 4,4'-bis[N,N'-(3-tolyl)amino]-3,3'-dimethylbiphenyl (HMTDP), and 3,3'-Dimethyl-N,N',N'',N''-tetra-*p*-tolyl-biphenyl-4,4'-diamine (R854).

4. The organic light emitting device of claim 1, wherein the electron transporting layer comprises a member of the group consisting of an oxadiazole, an oxadiazole derivative, a phenanthroline, a substituted benzoxazole, an un-substituted benzoxazole,

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doping in both layers

428/690
917
313/504
506
257/102
103

Phosphor
Phosphorescent
electro
triplet emitter
emission
organometallic
Indium &
emitter
or
emission

col 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100

Starburst
compounds
col 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100

col 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100

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ETC
dope w/ phos.

a substituted benzthiazole, and an un-substituted benzthiazole compound.

5. The organic light emitting device of claim 1, wherein the electron transporting layer comprises a member of the group consisting of 1,3-bis (N,N-t-butyl-phenyl)-1,3,4-oxadiazole (OXD-7), 2,9-dimethyl-4,7-diphenyl-1,10-phenanthroline (bathocuproine or BCP), a BCP derivative, and 3-phenyl-4-(1'-naphthyl)-5-phenyl-1,2,4-triazole (TAZ).

6. The organic light emitting device of claim 1, wherein the phosphorescent material comprises a member of the group consisting of Platinum(II) (2-phenylpyridinato-N,C^{2'}) (acetyl acetate) [Pt(ppy)(acac)], Platinum(II) (2-(p-tolyl)pyridinato-N,C^{2'}) (acetyl acetate) [Pt(tpy)(acac)], Platinum(II) (7,8-benzoquinolinate-N,C^{3'}) (acetyl acetate) [Pt(bzq)(acac)], Platinum(II) (2-(2'-(4',5'-benzothienyl)pyridinato-N,C^{3'}) (acetyl acetate) [Pt(btp)(acac)], Platinum(II) (2-(4',6'-difluorophenyl)pyridinato-N,C^{2'}) (acetyl acetate) [Pt(4,6-F₂ppy)(acac)], Platinum(II) (2-(4',5'-difluorophenyl)pyridinato-N,C^{2'}) (acetyl acetate) [Pt(4,5-F₂ppy)(acac)], Platinum(II) (2-(4',5'-difluorophenyl)pyridinato-N, C^{2'}) (2-picolinate) [Pt(4,5-F₂ppy)(pico)], and Iridium (2-(4',6'-difluorophenyl)pyridinato-N,C^{2'}) (2-picolinate) [Ir(4,6-F₂ppy)(pico)].

7. The organic light emitting device of claim 1, wherein the cathode comprises a member of the group consisting of magnesium silver and a magnesium silver alloy, and the anode comprises indium tin oxide (ITO).

8. An electronic device incorporating the organic light emitting device of claim 1, the

single rather
many
phosphorescent
phosphorescent
harvest
greater
eff-
emission
device
eff.

electronic device selected from the group consisting of a billboard, a sign, a computer monitor, a vehicle, a telecommunications device, a telephone, a printer, a television, a large area wall screen, a theater screen and a stadium screen.

intended
use
102

An organic light emitting device comprising:

an anode;

a first hole transporting layer over the anode;

a second hole transporting layer over the first hole transporting layer, wherein the second hole transporting layer is doped with a phosphorescent material;

a first electron transporting layer over the second hole transporting layer, wherein the first electron transporting layer is doped with the phosphorescent material;

a second electron transporting layer over the first electron transporting layer; and

a cathode over the second electron transporting layer.

10. The organic light emitting device of claim 9, wherein the organic light emitting device emits light in the blue range of the visible spectrum.

11. The organic light emitting device of claim 9, wherein the first hole transporting layer comprises a member of the group consisting of 4,4'-bis[N-(1-naphthyl)-N-phenyl-amino]biphenyl (α -NPD), N,N'-diphenyl-N,N'-bis(3-methylphenyl)-1,1'-biphenyl-4,4'-diamine (TPD), 4,4'-bis[N,N'-(3-tolyl)amino]-3,3'-dimethylbiphenyl (M14), 4,4',4''-tris(3-methylphenylphenylamino)triphenylamine (MTDATA), 4,4'-bis[N,N'-(3-tolyl)amino]-3,3'-dimethylbiphenyl (HMTDPD), and 3,3'-Dimethyl-N⁴,N⁴',N⁴'',N⁴''-tetra-*p*-tolyl-biphenyl-4,4'-diamine (R854), and wherein the second hole transporting

layer comprises a member of the group consisting of 4,4'-bis[N-(1-naphthyl)-N-phenyl-amino]biphenyl (α -NPD), N,N'-diphenyl-N,N'-bis(3-methylphenyl)-1,1'-biphenyl-4,4'-diamine (TPD), 4,4'-bis[N,N'-(3-tolyl)amino]-3,3'-dimethylbiphenyl (M14), 4,4',4''-tris(3-methylphenylphenylamino)triphenylamine (MTDATA), 4,4'-bis[N,N'-(3-tolyl)amino]-3,3'-dimethylbiphenyl (HMTPD), and 3,3'-Dimethyl-N⁴,N⁴,N⁴,N⁴-tetra-*p*-tolyl-biphenyl-4,4'-diamine (R854).

12. The organic light emitting device of claim 9, wherein the first hole transporting layer has an IP energy not more than about 0.7 eV greater than the IP energy of the anode.

13. The organic light emitting device of claim 12, wherein the first hole transporting layer has an IP energy not more than about 0.5 eV greater than the IP energy of the anode.

14. The organic light emitting device of claim 9, wherein the first electron transporting layer comprises a member of the group consisting of an oxadiazole, an oxadiazole derivative, a phenanthroline, a substituted benzoxazole, an un-substituted benzoxazole, a substituted benzthiazole, and an un-substituted benzthiazole compound, and wherein the second electron transporting layer comprises a member of the group consisting of tris-(8-hydroxyquinoline)aluminum (Alq₃) and a phthalocyanine compound.

15. The organic light emitting device of claim 9, wherein the first electron transporting layer comprises a member of the group consisting of 1,3-bis (N,N-t-butyl-phenyl)-1,3,4-oxadiazole (OXD-7), 2,9-dimethyl-4,7-diphenyl-1,10-phenanthroline (bathocuproine or BCP), a BCP derivative, and 3-phenyl-4-(1'-naphthyl)-5-phenyl-

Ionization Potential
optimize

limiting the IP
control hole
the holes
emitter
to

closer
energy of
layer to
the next

IP greater
from anode
to emitter

1,2,4-triazole (TAZ), and wherein the second electron transporting layer comprises copper phthalocyanine (CuPc).

16. The organic light emitting device of claim 9, wherein the phosphorescent material comprises a member of the group consisting of Platinum(II) (2-phenylpyridinato-N,C^{2'}) (acetyl acetate) [Pt(ppy)(acac)], Platinum(II) (2-(p-tolyl)pyridinato-N,C^{2'}) (acetyl acetate) [Pt(tpy)(acac)], Platinum(II) (7,8-benzoquinolino-N,C^{3'}) (acetyl acetate) [Pt(bzq)(acac)], Platinum(II) (2-(2'-(4',5'-benzothienyl)pyridinato-N,C^{3'}) (acetyl acetate) [Pt(btp)(acac)], Platinum(II) (2-(4',6'-difluorophenyl)pyridinato-N,C^{2'}) (acetyl acetate) [Pt(4,6-F₂ppy)(acac)], Platinum(II) (2-(4',5'-difluorophenyl)pyridinato-N,C^{2'}) (acetyl acetate) [Pt(4,5-F₂ppy)(acac)], Platinum(II) (2-(4',5'-difluorophenyl)pyridinato-N,C^{2'}) (2-picolinato) [Pt(4,5-F₂ppy)(pico)], and Iridium (2-(4',6'-difluorophenyl)pyridinato-N,C^{2'}) (2-picolinato) [Ir(4,6-F₂ppy)(pico)].

17. The organic light emitting device of claim 9, wherein the cathode comprises a member of the group consisting of magnesium silver and a magnesium silver alloy, and the anode comprises indium tin oxide (ITO).

18. An electronic device incorporating the organic light emitting device of claim 9, the electronic device selected from the group consisting of a billboard, a sign, a computer monitor, a vehicle, a telecommunications device, a telephone, a printer, a television, a large area wall screen, a theater screen and a stadium screen.

19. An organic light emitting device comprising:

a substrate;

an anode over the substrate;

a first hole transporting layer over the anode;

a second hole transporting layer over the first hole transporting layer, wherein the second hole transporting layer is doped with a phosphorescent material;

a first electron transporting layer over the second hole transporting layer, wherein the first electron transporting layer is doped with the phosphorescent material;

a second electron transporting layer over the first electron transporting layer; and

a cathode over the second electron transporting layer.

20. The organic light emitting device of claim 19, wherein the organic light emitting device emits light in the blue range of the visible spectrum.

21. The organic light emitting device of claim 19, wherein the first hole transporting layer comprises a member of the group consisting of 4,4'-bis[N-(1-naphthyl)-N-phenyl-amino]biphenyl (α -NPD), N,N'-diphenyl-N,N'-bis(3-methylphenyl)-1,1'-biphenyl-4,4'-diamine (TPD), 4,4'-bis[N,N'-(3-tolyl)amino]-3,3'-dimethylbiphenyl (M14), 4,4',4''-tris(3-methylphenylphenylamino)triphenylamine (MTDATA), 4,4'-bis[N,N'-(3-tolyl)amino]-3,3'-dimethylbiphenyl (HMTPD), and 3,3'-Dimethyl-N⁴,N⁴,N⁴,N⁴-tetra-*p*-tolyl-biphenyl-4,4'-diamine (R854), and wherein the second hole transporting layer comprises a member of the group consisting of 4,4'-bis[N-(1-naphthyl)-N-phenyl-amino]biphenyl (α -NPD), N,N'-diphenyl-N,N'-bis(3-methylphenyl)-1,1'-biphenyl-4,4'-diamine (TPD), 4,4'-bis[N,N'-(3-tolyl)amino]-3,3'-dimethylbiphenyl (M14), 4,4',4''-tris(3-methylphenylphenylamino)triphenylamine (MTDATA), 4,4'-bis[N,N'-

(3-tolyl)amino]-3,3'-dimethylbiphenyl (HMTPD), and 3,3'-Dimethyl-*N,N',N'',N'''*-tetra-*p*-tolyl-biphenyl-4,4'-diamine (R854).

~~22.~~ The organic light emitting device of claim 19, wherein the first hole transporting layer has an IP energy not more than about 0.7 eV greater than the IP energy of the anode.

~~23.~~ The organic light emitting device of claim 22, wherein the first hole transporting layer has an IP energy not more than about 0.5 eV greater than the IP energy of the anode.

~~24.~~ The organic light emitting device of claim 19, wherein the first electron transporting layer comprises a member of the group consisting of an oxadiazole, an oxadiazole derivative, a phenanthroline, a substituted benzoxazole, an un-substituted benzoxazole, a substituted benzthiazole, and an un-substituted benzthiazole compound, and wherein the second electron transporting layer comprises a member of the group consisting of tris-(8-hydroxyquinoline)aluminum (Alq₃) and a phthalocyanine compound.

~~25.~~ The organic light emitting device of claim 19, wherein the first electron transporting layer comprises a member of the group consisting of 1,3-bis (N,N-t-butyl-phenyl)-1,3,4-oxadiazole (OXD-7), 2,9-dimethyl-4,7-diphenyl-1,10-phenanthroline (bathocuproine or BCP), a BCP derivative, and 3-phenyl-4-(1'-naphthyl)-5-phenyl-1,2,4-triazole (TAZ), and wherein the second electron transporting layer comprises copper phthalocyanine (CuPc).

~~26.~~ The organic light emitting device of claim 19, wherein the phosphorescent material

comprises a member of the group consisting of Platinum(II) (2-phenylpyridinato-N,C²) (acetyl acetate) [Pt(ppy)(acac)], Platinum(II) (2-(p-tolyl)pyridinato-N,C²) (acetyl acetate) [Pt(tpy)(acac)], Platinum(II) (7,8-benzoquinolino-N,C³) (acetyl acetate) [Pt(bzq)(acac)], Platinum(II) (2-(2'-(4',5'-benzothieryl)pyridinato-N,C³) (acetyl acetate) [Pt(btp)(acac)], Platinum(II) (2-(4',6'-difluorophenyl)pyridinato-N,C²) (acetyl acetate) [Pt(4,6-F₂ppy)(acac)], Platinum(II) (2-(4',5'-difluorophenyl)pyridinato-N,C²) (acetyl acetate) [Pt(4,5-F₂ppy)(acac)], Platinum(II) (2-(4',5'-difluorophenyl)pyridinato-N, C²) (2-picolinato) [Pt(4,5-F₂ppy)(pico)], and Iridium (2-(4',6'-difluorophenyl)pyridinato-N,C²) (2-picolinato) [Ir(4,6-F₂ppy)(pico)].

27. The organic light emitting device of claim 19, wherein the cathode comprises a member of the group consisting of magnesium silver and a magnesium silver alloy, and the anode comprises indium tin oxide (ITO).

28. The organic light emitting device of claim 19, wherein the substrate comprises a member of the group consisting of plastic, metal and glass.

29. The organic light emitting device of claim 19, wherein the substrate is substantially transparent.

30. The organic light emitting device of claim 19, wherein the substrate is opaque, and the cathode is transparent.

31. An electronic device incorporating the organic light emitting device of claim 19, the

electronic device selected from the group consisting of a billboard, a sign, a computer monitor, a vehicle, a telecommunications device, a telephone, a printer, a television, a large area wall screen, a theater screen and a stadium screen.

32. An organic light emitting device comprising:
a substrate;
a cathode over the substrate;
a first electron transporting layer over the cathode;
a second electron transporting layer over the first electron transporting layer, wherein the second electron transporting layer is doped with a phosphorescent material;
a first hole transporting layer over the second electron transporting layer, wherein the first hole transporting layer is doped with the phosphorescent material;
a second hole transporting layer over the first hole transporting layer; and
an anode over the second hole transporting layer.

33. The organic light emitting device of claim 32, wherein the organic light emitting device emits light in the blue range of the visible spectrum.

34. The organic light emitting device of claim 32, wherein the first hole transporting layer comprises a member of the group consisting of 4,4'-bis[N-(1-naphthyl)-N-phenyl-amino]biphenyl (α -NPD), N,N'-diphenyl-N,N'-bis(3-methylphenyl)-1,1'-biphenyl-4,4'-diamine (TPD), 4,4'-bis[N,N'-(3-tolyl)amino]-3,3'-dimethylbiphenyl (M14), 4,4',4''-tris(3-methylphenylphenylamino)triphenylamine (MTDATA), 4,4'-bis[N,N'-(3-tolyl)amino]-3,3'-dimethylbiphenyl (HMTPD), and 3,3'-Dimethyl-N⁴,N⁴,N^{4'},N^{4'}-

tetra-*p*-tolyl-biphenyl-4,4'-diamine (R854), and wherein the second hole transporting layer comprises a member of the group consisting of 4,4'-bis[*N*-(1-naphthyl)-*N*-phenyl-amino]biphenyl (α -NPD), *N,N'*-diphenyl-*N,N'*-bis(3-methylphenyl)-1-1'-biphenyl-4,4'-diamine (TPD), 4,4'-bis[*N,N'*-(3-tolyl)amino]-3,3'-dimethylbiphenyl (M14), 4,4',4''-tris(3-methylphenylphenylamino)triphenylamine (MTDATA), 4,4'-bis[*N,N'*-(3-tolyl)amino]-3,3'-dimethylbiphenyl (HMTPD), and 3,3'-Dimethyl-*N,N',N',N'*-tetra-*p*-tolyl-biphenyl-4,4'-diamine (R854).

35. The organic light emitting device of claim 32, wherein the second hole transporting layer has an IP energy not more than about 0.7 eV greater than the IP energy of the anode.

36. The organic light emitting device of claim 35, wherein the second hole transporting layer has an IP energy not more than about 0.5 eV greater than the IP energy of the anode.

37. The organic light emitting device of claim 32, wherein the second electron transporting layer comprises a member of the group consisting of an oxadiazole, an oxadiazole derivative, a phenanthroline, a substituted benzoxazole, an un-substituted benzoxazole, a substituted benzthiazole, and an un-substituted benzthiazole compound, and wherein the first electron transporting layer comprises a member of the group consisting of tris-(8-hydroxyquinoline)aluminum (Alq₃) and a phthalocyanine compound.

38. The organic light emitting device of claim 32, wherein the second electron transporting

layer comprises a member of the group consisting of 1,3-bis (N,N-t-butyl-phenyl)-1,3,4-oxadiazole (OXD-7), 2,9-dimethyl-4,7-diphenyl-1,10-phenanthroline (bathocuproine or BCP), a BCP derivative, and 3-phenyl-4-(1'-naphthyl)-5-phenyl-1,2,4-triazole (TAZ), and wherein the first electron transporting layer comprises copper phthalocyanine (CuPc).

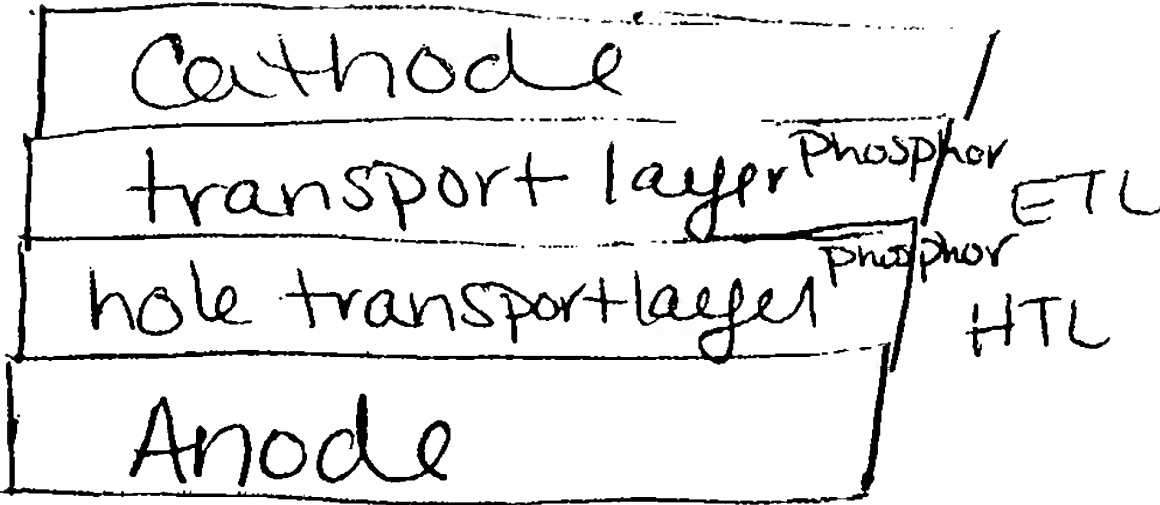
39. The organic light emitting device of claim 32, wherein the phosphorescent material comprises a member of the group consisting of Platinum(II) (2-phenylpyridinato-N,C^{2'}) (acetyl acetate) [Pt(ppy)(acac)], Platinum(II) (2-(p-tolyl)pyridinato-N,C^{2'}) (acetyl acetate) [Pt(tpy)(acac)], Platinum(II) (7,8-benzoquinolinato-N,C^{3'}) (acetyl acetate) [Pt(bzq)(acac)], Platinum(II) (2-(2'-(4',5'-benzothienyl)pyridinato-N,C^{3'}) (acetyl acetate) [Pt(btp)(acac)], Platinum(II) (2-(4',6'-difluorophenyl)pyridinato-N,C^{2'}) (acetyl acetate) [Pt(4,6-F₂ppy)(acac)], Platinum(II) (2-(4',5'-difluorophenyl)pyridinato-N,C^{2'}) (acetyl acetate) [Pt(4,5-F₂ppy)(acac)], Platinum(II) (2-(4',5'-difluorophenyl)pyridinato-N, C^{2'}) (2-picolinato) [Pt(4,5-F₂ppy)(pico)], and Iridium (2-(4',6'-difluorophenyl)pyridinato-N,C^{2'}) (2-picolinato) [Ir(4,6-F₂ppy)(pico)].

40. The organic light emitting device of claim 32, wherein the cathode comprises a member of the group consisting of magnesium silver and a magnesium silver alloy, and the anode comprises indium tin oxide (ITO).

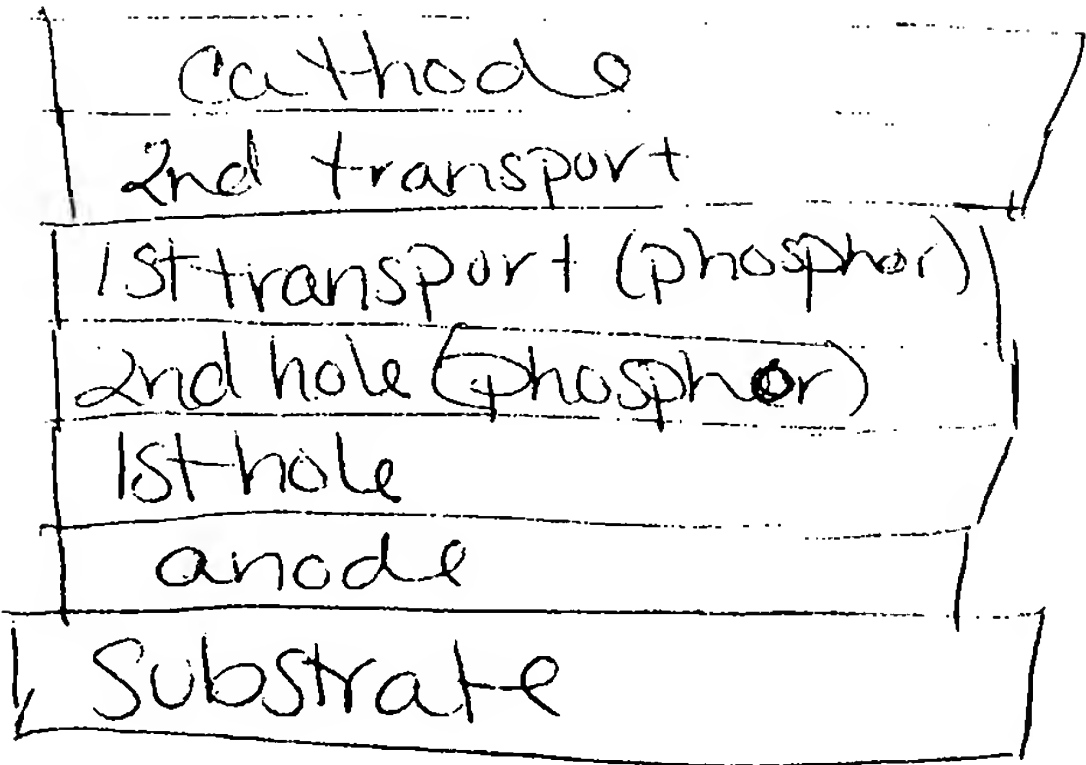
41. The organic light emitting device of claim 32, wherein the substrate comprises a member of the group consisting of plastic, metal and glass.

42. The organic light emitting device of claim 32, wherein the substrate is substantially transparent.
43. The organic light emitting device of claim 32, wherein the substrate is opaque, and the anode is transparent.
44. An electronic device incorporating the organic light emitting device of claim 32, the electronic device selected from the group consisting of a billboard, a sign, a computer monitor, a vehicle, a telecommunications device, a telephone, a printer, a television, a large area wall screen, a theater screen and a stadium screen.

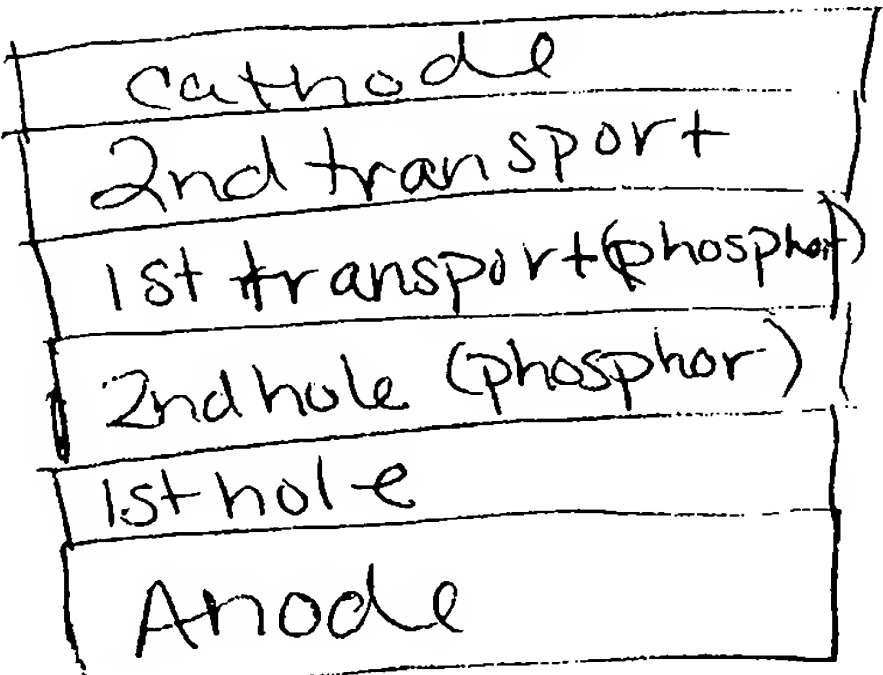
Claim 1.



Claim 19:



Claim 9:



Claim 32:

